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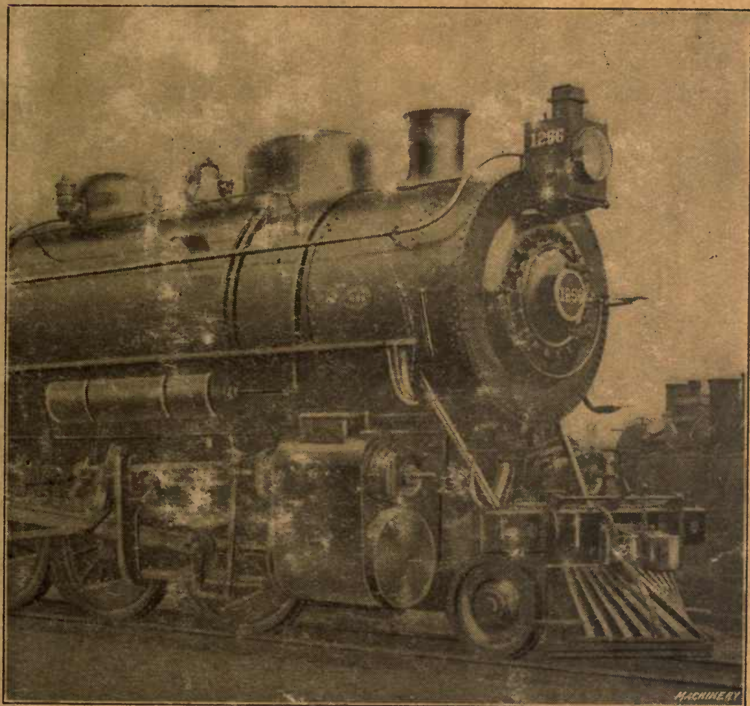
RAILWAY REPAIR SHOP PRACTICE

BY FRANKLIN D. JONES

FROM THE TRENTON SHOPS OF THE PENNSYLVANIA RAILROAD

SECOND EDITION



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CONTENTS

RAILWAY REPAIR SHOP PRACTICE*

Repair work is usually attractive to the machinist who has a natural bent for mechanics, doubtless because his judgment and what ability he may have are brought into play more frequently than in the construction of new machinery. As the steam locomotive is a power plant in itself, the general repairs that are required occasionally are particularly interesting, and also instructive in principles of a practical nature that can be applied in the repair and construction of many other kinds of mechanisms.

In overhauling a locomotive, the necessary repairs are diversified, and require, in addition to the skill of the machinist, experienced boilermakers, blacksmiths, coppersmiths, and air-brake specialists. We cannot, however, cover all the various phases of locomotive repair work in this brief treatise, and shall therefore confine our attention to some of the principal operations within the field of the machinist. The particular tools and methods referred to represent the practice at the Pennsylvania Railroad's large repair shops at Trenton, N. J. These shops are modern in their management and equipment, and have a capacity for overhauling sixty-six locomotives a month—this being an average figure. As many as eighty locomotives have, however, received repairs during one month, and ordinarily from twenty to twenty-three engines are being overhauled at one time. It should be mentioned that practically all the operations referred to are common to railroad shops and well known to experienced railway machinists, but they will doubtless be of interest and value to mechanics engaged in other lines of work.

Dismantling the Locomotive

Before the work of repairing can begin, it is necessary to take the locomotive apart; the first step is the removal of the driving wheels. The method of accomplishing this, in a modern shop, is to lift the boiler and its attached parts vertically from the wheels after the binder or pedestal braces (*A*, Fig. 22), the main rods, and those parts of the valve-operating mechanism which would interfere, have been removed. Fig. 2 shows an engine of the freight class being dismantled in this way. Two cranes having a capacity, in this case, of 65 tons each, are used. The crane for lifting the rear end carries a large steel cradle or sling having a heavy crossbar which passes beneath the engine frames, and the other crane is connected to the front ends of the frames, with the chain clamps shown. When the boiler is raised a few feet above the wheels, it is moved laterally to a position about midway between the pit tracks and is then carried to a vacant space on one of the tracks, where it is lowered on blocks and jacks. This entire oper-

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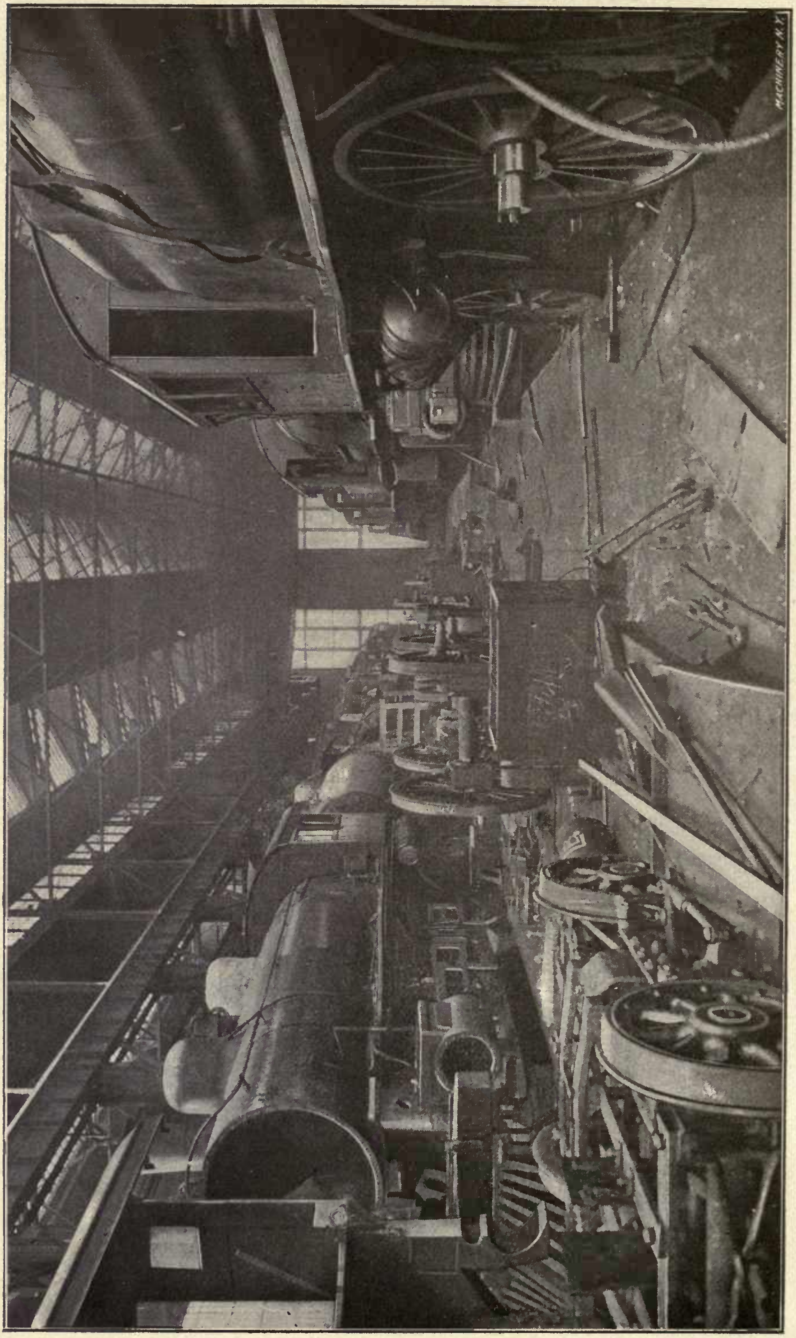


Fig. 1. View in the Erecting Department of the Trenton Shops, Pennsylvania Railroad

ation is performed in a surprisingly short time, owing to the effectiveness of cranes for this work.

The way the "stripped" or de-wheeled engines are arranged in rows along the parallel pit tracks is illustrated in Fig. 1, which is a view in the erecting department. This illustration also indicates the extent to which a locomotive is taken apart for general overhauling. Ordinarily, the boiler, frame, cylinders, and cab remain intact, as shown in the foreground to the left; it may, however, be necessary to remove the cab when extensive repairs have to be made on the firebox, and occasionally the boiler and frames are separated.

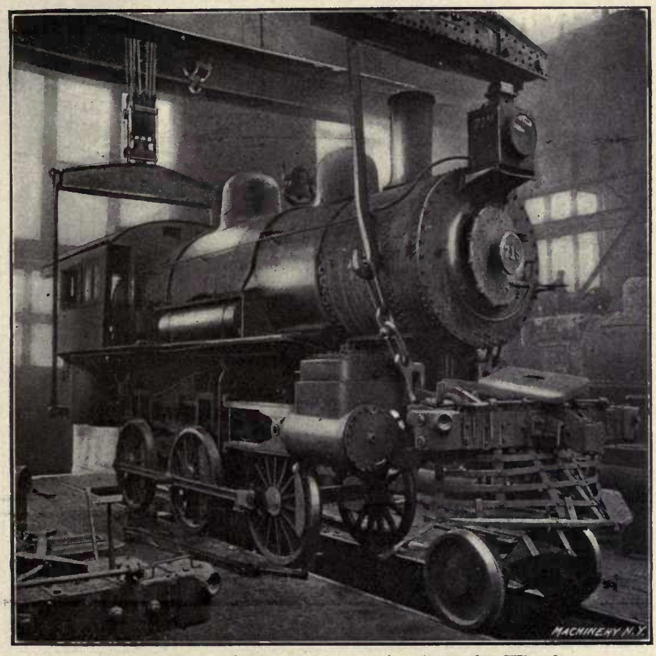


Fig. 2. Cranes lifting a Locomotive from the Wheels

It should be explained that when the repair tracks are arranged as shown in Fig. 1, the shop is known as a "longitudinal" shop, whereas the "cross" type has comparatively short tracks extending in a crosswise direction. There is a difference of opinion regarding the merits of the two arrangements. Many prefer the longitudinal type as being conducive to greater flexibility, more economical use of track space, and a greater output from a given amount of track space.

In some shops which are not equipped with heavy cranes, it is the practice to remove the wheels from beneath, one arrangement being to place the locomotive over a special "drop-pit," which has a section of track that is long enough to hold the wheels, and is so constructed that it can be lowered. After jacks have been placed beneath the engine frames and the necessary parts have been disconnected, the

track and the wheels are lowered together and the wheels rolled out through the pit onto a "transfer table" which travels between the different pits. This method, however, is not so efficient as lifting the boiler by overhead cranes.

After the wheels and boiler are separated, all parts, such as the spring rigging, pistons, crossheads and guides, steam chests, valves, etc., are stripped from the frame and cylinders, and the driving boxes and eccentrics (if the engine has a Stephenson link motion) are removed from the main axles. In case the locomotive requires a new firebox, which, of course, means sending the entire boiler to the boiler

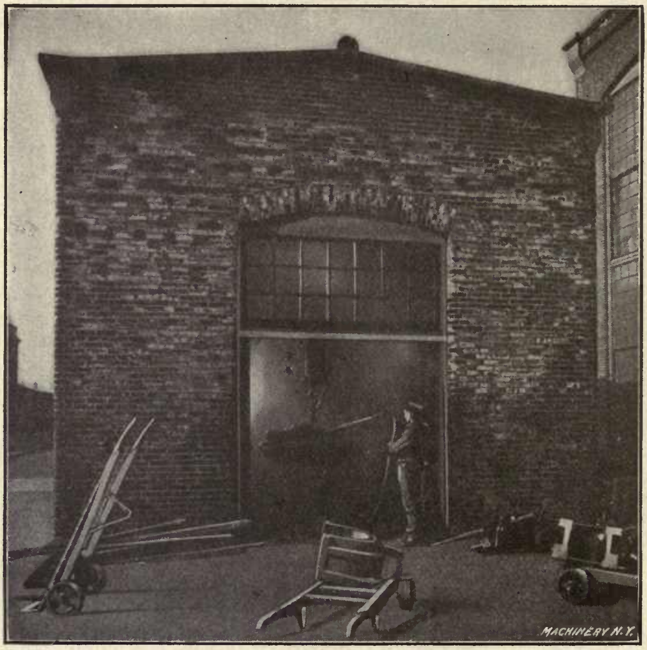


Fig. 3. Lye-house where Parts to be Repaired are Cleaned

shop, all parts such as the steam dome cover, steam chests and covers, pipes, running boards, and similar pieces which do not need repairs, are stored in bins or cellars located between the pit tracks. The large covers for these cellars have rings for attaching crane hooks, so that they can easily be removed when necessary.

Practically all the parts requiring repairs, after being stripped from the locomotive, are taken to a small but very important building adjacent to the shop, known as the "lye-house," where the grease and dirt are removed. A view of the lye-house is shown in Fig. 3. The parts are cleaned by immersing them in boiling water containing a small percentage of lye or potash. A number of pieces are immersed at one time by placing them on a chain-supported platform which is raised and lowered by an air hoist. After being withdrawn from the hot

lye bath, the parts are washed with cold water by a hose, as shown in Fig. 3; they are then ready for inspection and repairs. The number of the engine to which the different pieces belong is stamped permanently on them, or else a tin tag is attached to them so that their identity can be determined.

Boring and Re-lining the Cylinders

The reciprocating motion of the pistons in the locomotive cylinders gradually wears shoulders at each end of the piston's stroke, and the cylinders are also worn more or less out of round, so that it is necessary to rebore them. This operation is done without removing the cylinders, by means of a portable boring-bar. One of these boring-bars is shown applied to a cylinder in Fig. 4. The bar proper is mounted

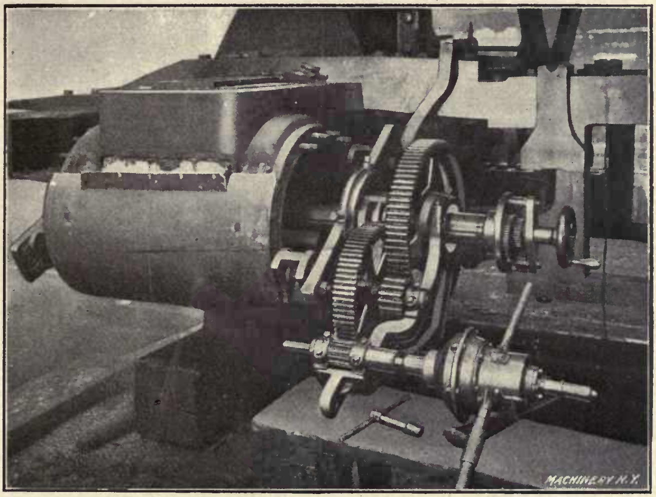


Fig. 4. Reboring a Locomotive Cylinder

in brackets attached to the front and back ends of the cylinder, and it is rotated by a pneumatic motor which drives through a train of reduction gearing, thus giving the bar a comparatively slow speed. Rigidly attached to the bar, is a tool-head containing from one to three tools which, as the bar revolves, are slowly fed lengthwise through the cylinder by a feeding mechanism which can be adjusted to give a fine or a coarse feed, as required. In setting up this boring-bar, the brackets are first attached to the cylinder ends by the cylinder studs, with the bar bushings approximately in a central position. The bar, without the driving mechanism, is then passed through the brackets and is set central with the counterbores at the ends. It is located with reference to the counterbores because they have not been subjected to wear and are, therefore, concentric with the original bore. When the bar is set, the driving and feeding mechanism is attached and the motor connected. Ordinarily, a cylinder can be trued by taking one roughing and one finishing cut, though more may be

required if the cylinder is badly worn. When two or three cutters are used, the bore can often be finished with a single passage of the tools, one of which is ground to leave a smooth surface.

When a cylinder has been enlarged by reboring until its diameter is one inch above the normal or original size, the diameter is reduced by the insertion of a cast-iron lining or bushing. In machining these bushings, they are first rough turned on the outside in a lathe, as shown in Fig. 5, the work being mounted on centered spiders, as shown. After roughing the outside, the bushing is faced 1/16 inch longer than the cylinder, and the inside is bored to the finish size by a special bar held between the lathe centers, as shown in Fig. 6. The work is held in rests or supports which are attached to the lathe bed, and the bar is driven by the lathe. The tool-head, which carries two

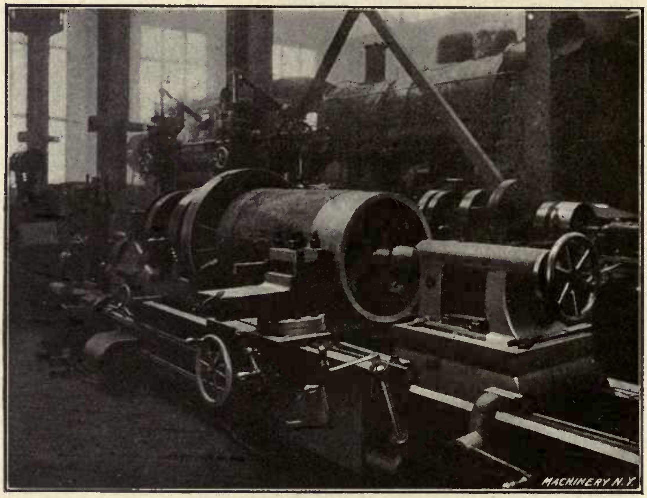


Fig. 5. Rough-turning a Cylinder Lining

tools, located 180 degrees apart, is fed along the bar by a star feed mechanism, shown attached to the bar and the tailstock spindle. When the bore is finished, centered disks which fit the finished counterbores, are placed in the ends of the bushing, and the bushing is then turned on the outside slightly larger than the diameter of the cylinder, which has previously been bored true. The object in rough turning the outside of the bushing prior to boring it, is to avoid the distortion which would probably occur if this hard outer surface were removed last. These linings are finished before being placed in the cylinders, which includes the cutting of ports to match the steam ports in the cylinders. When completed, the cylinders are heated by a fuel oil burner which expands them sufficiently to allow the bushings to be inserted by hand. After the cylinders become cold, the bushings, which were finished slightly over-size, are gripped tightly and additionally supported against longitudinal movement by the cylinder heads. The extra length allowed in turning is faced off after the cylinder is cold.

Facing Valve Seats—Scraping Valve and Seat–Fitting False Seats

If a locomotive is equipped with slide valves, the valve faces and the seats on the cylinders become worn and need to be planed true. The planing operation on the cylinder seats is done by a small rotary

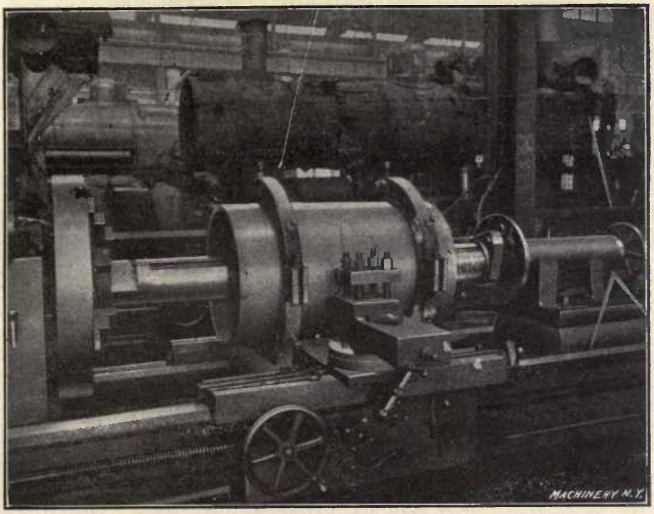


Fig. 6. Boring a Cylinder Lining

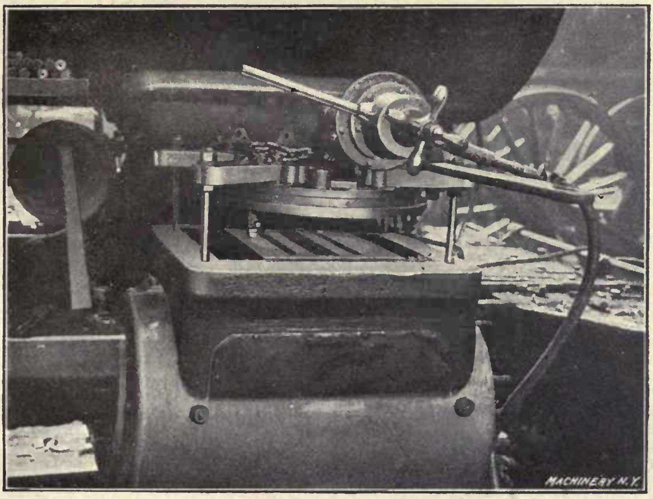
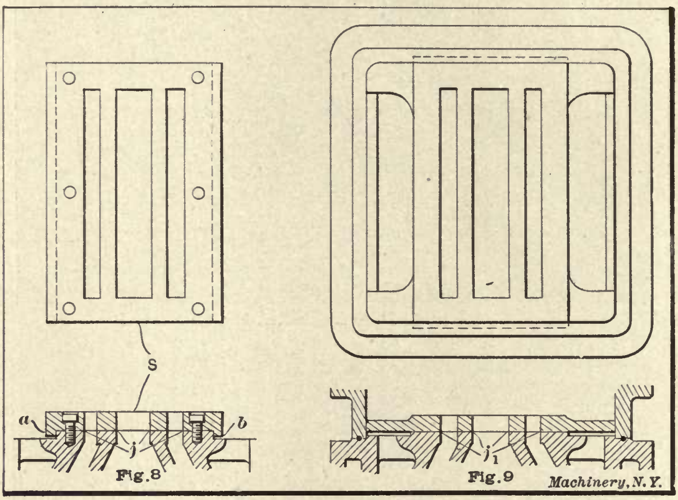


Fig. 7. Facing a Slide-valve Seat

planing machine that is mounted on the cylinder, as shown in Fig. 7. This particular machine is attached to the cylinder by four studs which are screwed into the corner holes for the steam-chest studs. The planing tool has a circular movement and is fed by a star feed.

After the seat and valve are planed, they are sometimes scraped to obtain a more perfect bearing. The method followed is to first scrape the valve to a surface-plate and then apply black or red lead to the valve face which is used as a surface-plate while scraping the seat. The black or red marks (as the case may be) made by rubbing the valve across the seat, show the high spots, which should be removed with a flat-end scraper. This operation is repeated until there are bearing marks on practically every part of the seat. It is not necessary to obtain a finely spotted bearing, but the test marks should show a good general bearing, evenly distributed. Very often a valve and seat which have just been planed do not require any further finishing, as the machined surfaces are exact enough to make a good joint.



Figs. 8 and 9. Methods of applying a False Seat

After the valve seat has been planed so often that it is reduced almost to the level of the cylinder surface, it is raised to the original height (if the cylinder is good otherwise) by putting on what is known as a "false seat." The old seat is first planed true, after which the new or false seat *S*, Fig. 8, is fitted to it by scraping, in order to obtain steam-tight joints at *j*. The location and style of the bolts used for holding the false seat are shown in the plan and sectional views. By having projections at *a* and *b*, any tendency of the seat to move with the valve is resisted, independently of the bolts. The heads of the bolts, which are of steel, should be about 1/16 inch below the upper surface of the seat, to avoid the uneven wear which would take place if the steel bolt heads were flush with the softer and faster-wearing cast-iron seat.

Fig. 9 illustrates another method of applying a false seat, which is preferred on some roads. Projections or lugs cast integral with the seat are fitted to the inside of the steam chest and hold the seat in position without the use of bolts. The seat is, of course, carefully

scraped to a good bearing on the cylinder, and the joints j_1 are sometimes finished by grinding with oil and emery. There are projections on this seat (as shown by the dotted lines) which fit into slots planed in the steam chest, so that in case the seat should break, it could not lift up and interfere with the movement of the valve.

Balanced Slide Valves—Piston Valves

Practically all the slide valves now in use, particularly on large locomotives, are of the balanced type, which means that the steam pressure is excluded from most of the upper surface of the valve. There are different designs of balanced valves, but comparatively few of the large number which have been patented have ever been adopted by the railroads. A type which is extensively used on the Pennsylvania and other roads is shown in Fig. 10; the style of steam chest cover used is also illustrated. The top of this valve has four grooves *g*

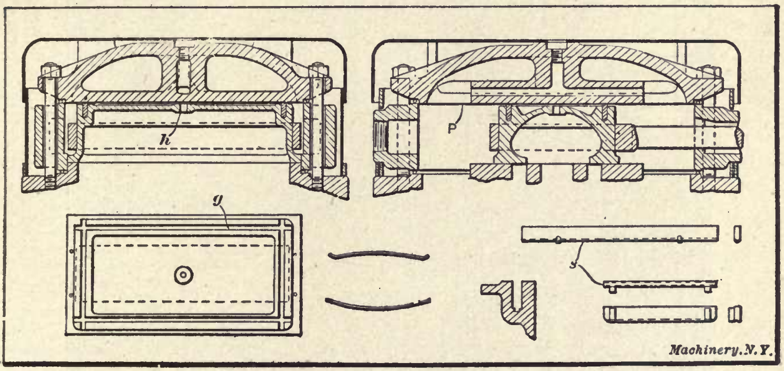


Fig. 10. Balanced Slide Valve and Steam Chest

which contain packing strips *s*, held by semi-elliptic springs against what is known as a "pressure plate" *P*. The rectangular area enclosed by the packing strips is relieved of practically all pressure, so that the friction between the valve and its seat is greatly lessened, with the advantage that the mechanism which actuates the valve is subjected to less strain and the locomotive can be reversed with much less exertion on the part of the engineer. The wear between the valve and its seat is also reduced because of the diminished pressure and friction. The small hole *h* allows any steam that might leak past the packing strips to escape through the exhaust, thus preventing an accumulation of pressure which would soon overcome the balancing effect.

The repeated backward and forward movement of the packing strips on the pressure plate results in wear, which, in the case of the plate, is remedied by planing, as shown in Fig. 11. As the plate must be kept down close to the valve, the same amount that is planed off in truing it, is also taken off the joint of the cover, if the plate and cover (as in the design illustrated) is a one-piece casting. If the plate is a separate part, it is "lined down", prior to planing, by inserting washers of the proper thickness between it and the cover to which

it is bolted. The packing strips should fit quite closely in their slots, but be free to move vertically. After a valve of this type has been in service for some time, the valve slots will probably need to be planed true and new packing strips fitted to them.

A great many modern locomotives are fitted with cylindrical or piston valves, instead of flat-seated slide valves. These piston valves have packing rings *r* at the ends, as shown in Fig. 12, which form the working edges and control the points of admission and release of the steam to and from the cylinders. The chambers or steam chests for the piston valves are provided with linings or bushings in which the steam ports are located. There are two of these lining bushings *B*, in the steam chest illustrated in Fig. 12, and as these are worn by the reciprocating action of the valve, they are

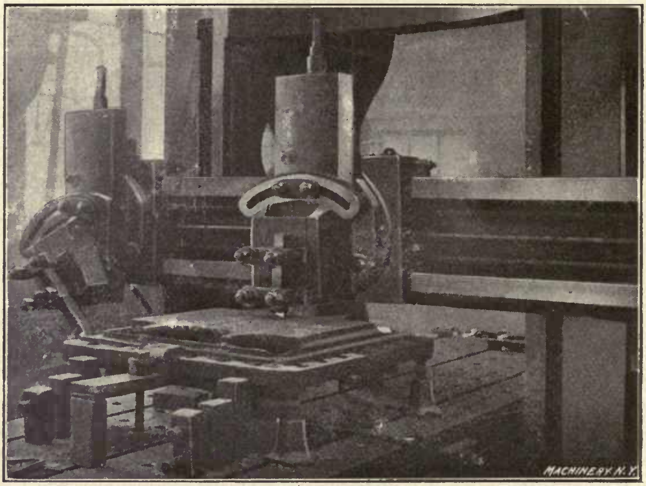


Fig. 11. Planing the Pressure Plate of a Steam-chest Cover

renewed instead of being trued by boring (as in the case of the cylinders), in order to keep the valve and its packing to a standard diameter. The inside of the bushing is finished in a vertical boring mill. The first operation is to rough bore the inside and face the upper end; the work is then turned up-side-down for finishing the bore and beveling the end, the chuck jaws being released to prevent springing the work. The outside is then turned, while the work is held on a special expanding mandrel. This mandrel, shown to the left in Fig. 13, is composed of two conical disks that are separated by a number of equally spaced bars or strips, the ends of which are a sliding fit in T-slots cut in the conical peripheries of the disks. As the disks are moved longitudinally along the central arbor, these expansion bars move in or out radially, thus decreasing or increasing the diameter as desired. To the expansion bars of the mandrel illustrated are bolted extension strips for holding the large bushing shown to the right. The finished bushings, which are turned slightly larger than the bore

Operations on the Piston and Rod

The enlargement of the cylinders by reboring makes it necessary to increase the diameter of the pistons, as the difference between the diameter of a cylinder and piston should not exceed 3/16 or 1/4 inch, notwithstanding that the piston is equipped with expansion rings

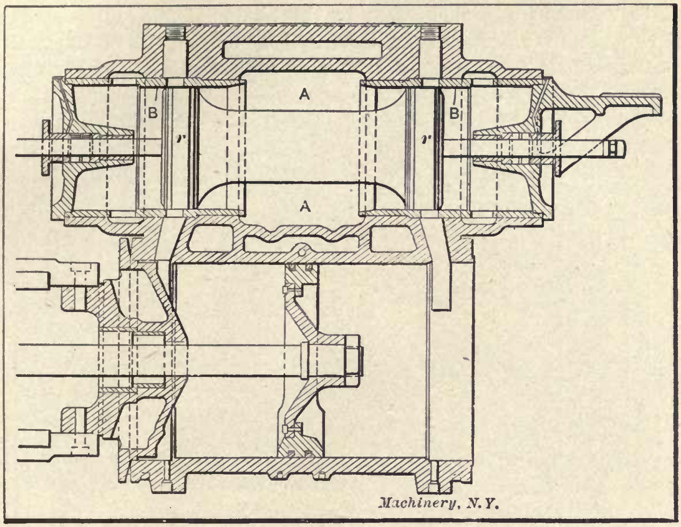


Fig. 12. Sectional View of Cylinder and Steam Chest with Piston Valve

which bear against the cylinder walls. A design of piston which enables this increase in diameter to be quickly made and at small cost, is shown in Fig. 14. The body of the piston is of cast steel and attached to it is a cast-iron rim *R*, containing the packing rings. To

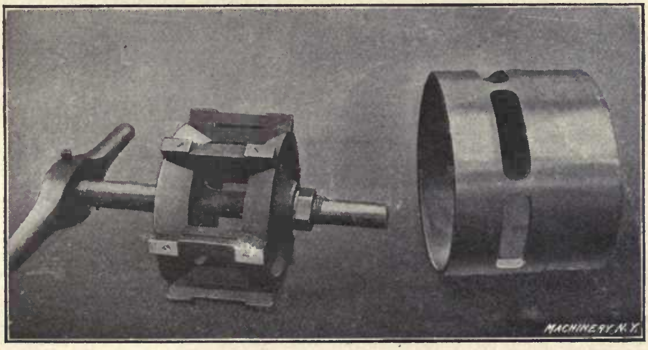


Fig. 13. Steam-chest Bushing and Expanding Mandrel

increase the diameter of the piston this rim is simply replaced by one of larger size. In fitting this rim, the inside is first finished in the boring mill, and the diameter *d* is made about 0.008 or 0.010 inch smaller than the cast-steel center, for a shrink fit. The sides of the

rim, with the exception of the flange, are next milled as in Fig. 15, after which the rim is heated and shrunk onto the center casting. Holes are then drilled and tapped for the rim bolts which are riveted over to prevent them from backing out. The rim is then turned on the outside and the packing ring grooves cut as shown in Fig. 16, the piston-rod being used as a mandrel. The flanges *f* (Fig. 14) are also turned to conform approximately to the shape of the cylinder heads, which the piston approaches within 1/8 or 3/16 inch at the ends of its stroke. These flanges extend around one-third of the ring circumference and are placed on the bottom to give a broad bearing or wearing surface. The cast-iron packing rings *r* are turned 1/8 inch larger in diameter than the cylinder bore. A section of the rings is then cut away at *c* which allows them to be sprung into the cylinder, against

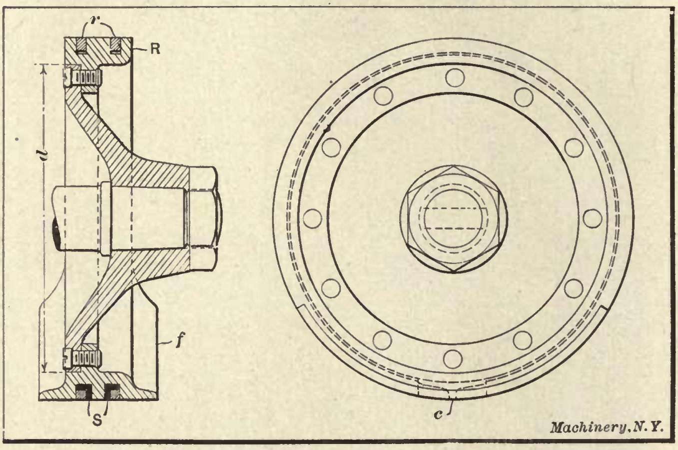


Fig. 14. Cast-steel Single-plate Piston with Removable Rim

which they press, thus forming a joint. The openings in the ring permitting of this flexibility are always kept in the bottom of the cylinder by cast-brass L-shaped segments *S*. These segments have a cross piece at *c* which comes between the ring ends, thus preventing them from turning. The reason that the ring openings are placed in the bottom of the cylinder is to prevent steam from blowing through them. As the piston rests on the bottom part of the cylinder, very little steam can leak through the openings when they are at the bottom, for the rim or body of the piston forms its own joint at this point.

The continual in-and-out movement of the piston-rod results in wear on that part of the rod which passes through the packing, so that shoulders are formed at points corresponding to the ends of the stroke. In many shops it is the practice to true the rods by turning them in the lathe, a finished surface being obtained by using a file and emery cloth; but the modern method of grinding the rods is much superior to turning, as less time is required and a better finish is obtained.

Fig. 17 shows a piston-rod that has been trued in this way, in place in the grinding machine. The valve stems are also trued by grinding. When a new rod is required, it is rough turned in the lathe and then finished in the grinder, as this is the most economical way of doing the work.

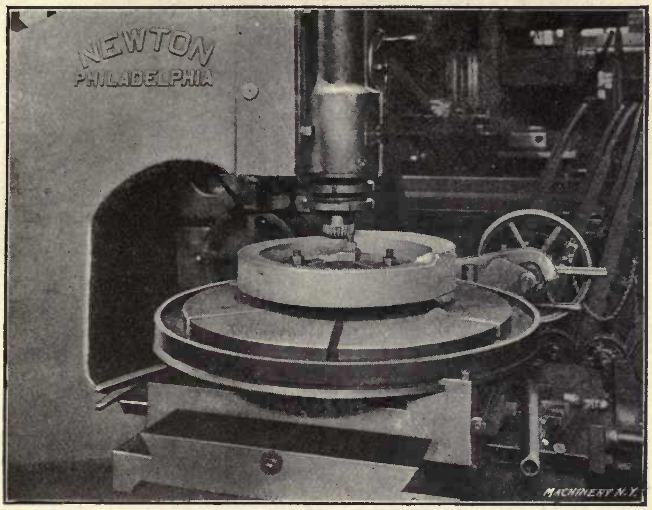


Fig. 15. Milling the Side of a Piston Rim

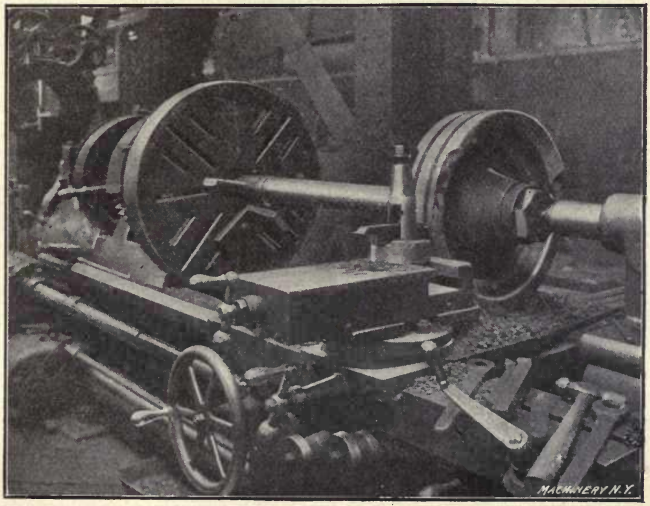


Fig. 16. Turning the Piston

The slot in a new rod for the crosshead key is drilled with the jig shown in Fig. 18. The crosshead end of the rod is inserted in a hole of corresponding taper in the jig body, and the jig proper *J*, which has a number of closely spaced holes equal to the length of the slot, is adjusted by the set-screws shown, to the proper longitudinal posi-

tion. As one end of the slot is made tapering to conform to the key which retains the rod in the crosshead, the hole for that end is drilled at an angle, the drilling plate *J* being tilted by a liner *l*, and then set level with the drill press table.

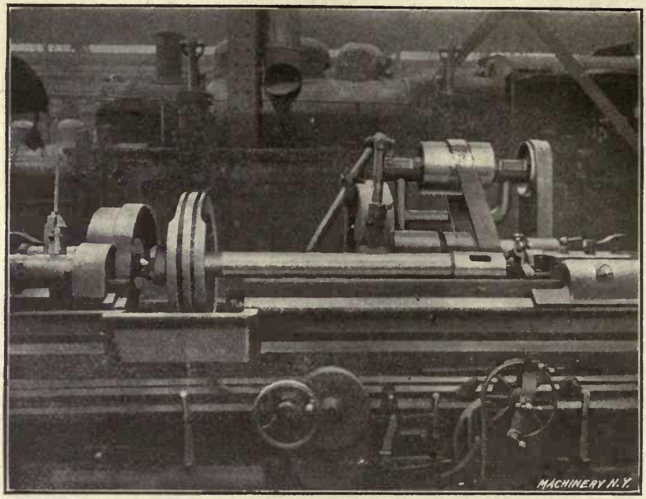


Fig. 17. Truing a Piston-rod by Grinding

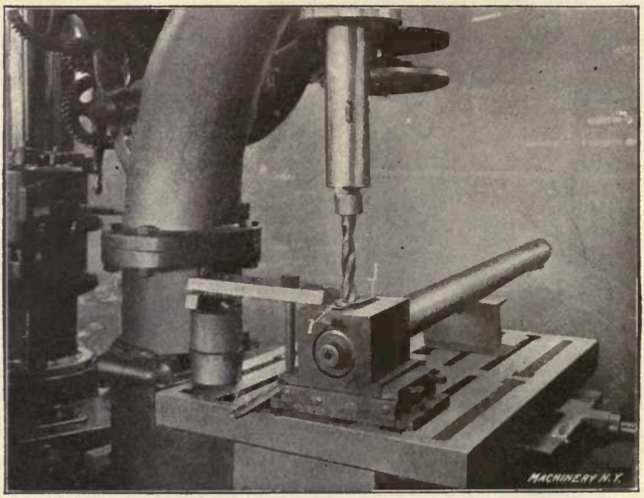


Fig. 18. Jig for Drilling Keyslots in Piston-rods

Turning the Driving Wheels

The driving wheels of a locomotive, or rather the tires on the wheels, are worn considerably, partly by the abrading action of the brake shoes and partly by the rolling or slipping of the wheels on the rails and the grinding of the flanges when rounding curves. As

it is impossible to make all tires to exactly the same degree of hardness, some wear faster than others which results in a gradual change in the diameters of the wheels. Any difference in diameter is particularly objectionable, as the small wheels tend to revolve a greater number of times in a given distance than the larger ones, and this would, of course, actually occur were it not for the connecting-rods which keep the crankpins in alignment and the wheels rotating in unison; in doing this, however, the rods are subjected to severe strains.

The turning of the worn tires is done in powerful wheel lathes, and the operation is one of the most efficient connected with machine shop work. One of the lathes used for wheel work is shown in Fig. 19, turning a small pair of driving wheels. The smallest wheel of a set

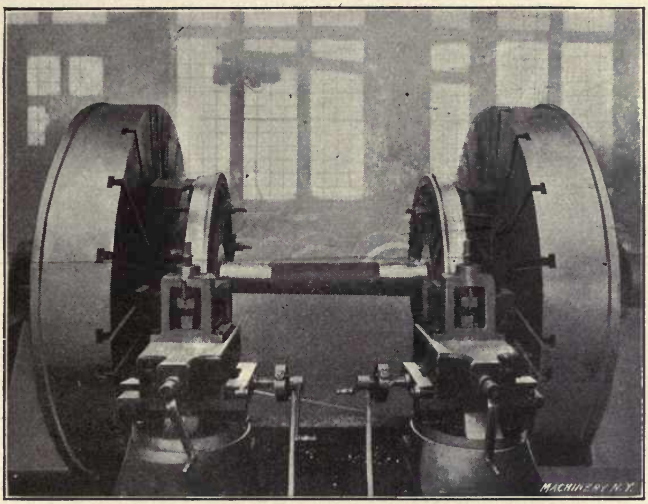


Fig. 19. Turning Driving-wheel Tires

is turned first so that the larger ones can be finished with reference to it. A roughing cut is first taken across both tires by two tools which operate simultaneously. A very coarse feed is used on the roughing cuts, the tools on the particular machine illustrated feeding as much as 9/16 inch per revolution of the work. As a round-nose tool is used, this feed leaves a very rough surface which is removed, in finishing, by special form tools. For a flanged tire, there are two of these tools, one of which forms the flange and tread (an operation which has just been completed on the wheels illustrated), and the other, that part of the tire which ordinarily extends beyond the rail. In turning a "blind" tire, or one without a flange, three form tools are used, there being one flat tool for the central part of the tire, and right- and left-hand tools for tapering it slightly on each side of the tread. Tires which have been turned so often that another turning would reduce the thickness below the limit of safety, are replaced by new ones. When this is necessary, the old tires, which are shrunk on the wheel centers, are removed by heating with a gasoline burner.

The burner proper encircles the tire and has a number of perforations for the gas flames which come in contact with the tire, thus expanding it sufficiently to permit of its removal. The new tires are bored smaller than the diameter of the wheel center, after which they are heated and shrunk in place. A common allowance for tires is 0.001 inch for each inch of diameter.

On the Pennsylvania, the tires are prevented from shifting laterally by a series of segment-shaped plates that are riveted to the inner sides of the wheel center rims and engage annular slots cut in the tires. The tires also have shoulders that abut against the wheel center on the outside, so that any lateral movement is prevented in case they are loosened by the heat and resulting expansion due to a prolonged

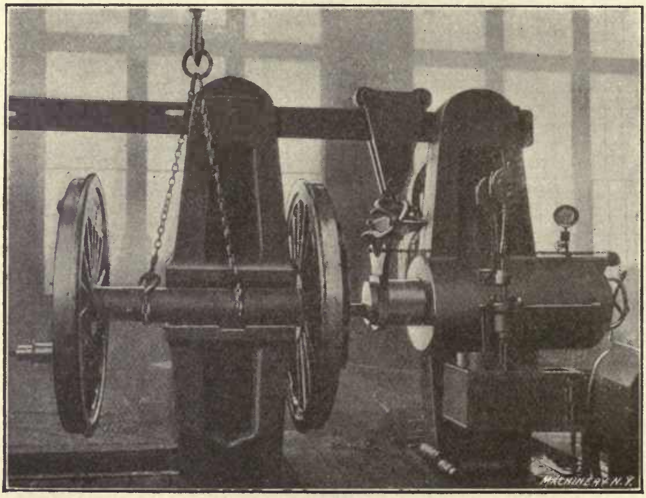


Fig. 20. Forcing a Crankpin into a Wheel Center by a Hydraulic Press

application of the brakes on a grade, or a slipping of the wheels on the rails. The journals or bearings for the driving boxes are also turned true in the wheel lathes, although the particular machine illustrated in Fig. 19 is not designed for doing this work.

Renewing Crankpins

When the diameter of the crankpin, because of wear and repeated turning or truing operations, is reduced more than ¼ inch below its original size, the pin is removed and replaced by a new one. The turning of the pin is a lathe operation of an obvious nature, but as the pin is held in the wheel center by being forced into it, the turning of this tightly-fitting part requires considerable accuracy. To obtain this tight fit, the diameter of the pin is made a few thousandths inch larger than the hole in the wheel. This difference is made great enough to require a pressure of about 10 tons per inch of pin diameter for cast-iron wheel centers, and 15 tons per inch for steel centers, for forcing the pin into the wheel. Fig. 20 shows how a pin is forced

into place in a hydraulic press equipped with a gage showing the pressure in tons that is being applied. The actual tonnage required varies even though the same allowance be made for pins of corresponding diameters, as the pressure is affected by the condition of the hole, the mass of metal surrounding it and the kind of metal. A new hole, or one that has just been bored, will offer less resistance than an old hole, as the latter will be harder and more compact. An allowance, or difference between the diameters of the pin and bore, of 0.001 inch for each inch of diameter, plus 0.002 inch, is a fair average value for crankpin fits, though some railroad shops use a greater allowance than would be obtained by this rule. The press shown in Fig. 20 has a maximum capacity of 400 tons, and it is also used for forcing wheel centers onto their axles.

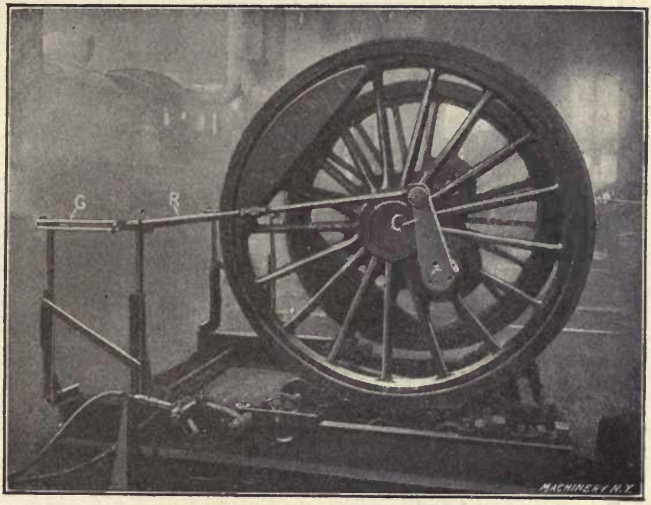


Fig. 21. Gage for Setting Return Cranks of Walschaerts Valve Gear

If the main crankpin of a locomotive having the Walschaerts valve gear is renewed, it is necessary to attach the return crank to the end of the main pin, after the latter has been forced into place. To locate this crank in the correct position, the apparatus illustrated in Fig. 21 is employed. The hub of crank *C* is inserted in the end of the main pin, and the crank is connected by rod *R* with a block which slides between the guides *G*. The top bar of the guides is graduated in inches, and they are adjusted to the height of the wheel centers when testing. The graduations are numbered in the ascending order from a central zero mark, and the slide block has a pointer which shows the stroke of the return crankpin. The test is made by rotating the wheels which are mounted on rollers turned by a pneumatic motor connected through reduction gearing, as shown. If the pointer travels farther from the zero mark on one side than on the other, the length of connecting-rod *R* is changed—by turning a right- and left-hand nut—until the zero mark is central with the pointer's travel. The gradua-

tions will then show the exact throw of the crank, which is adjusted toward or away from the wheel center until the throw indicated by the scale conforms to the required standard. This crank is secured to the main pin, after being set, by three screws located 120 degrees apart, which act as keys.

Driving-box Repairs

As the driving-wheel boxes support most of the weight of the locomotives and contain the journals for the driving wheels, they require particular attention. As those familiar with a locomotive know, each box is located between two frame jaws and is held in place by a shoe *S* (Fig. 22) at the front and a wedge *W* at the rear. The shoes form a bearing surface for the front side of the boxes and the wedges provide means of adjustment. The wedges are set up tight enough to prevent any play, but the boxes should be free to move vertically between the

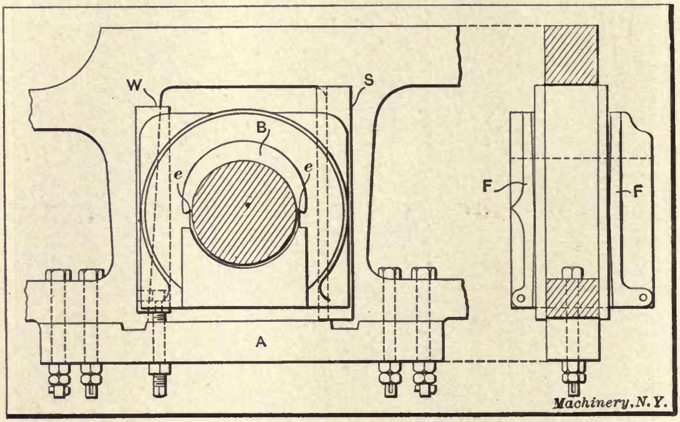


Fig. 22. Driving-wheel Box, Frame, Jaws and Pedestal Brace

frame jaws, as the frame and boiler are spring supported, and, therefore, have more or less vertical movement. This continual working of the boxes up and down wears the sides and also the faces of both the shoes and wedges, so that these surfaces have to be planed true. Before the sides of the boxes are planed, however, the brass shells or bearings *B* are renewed, or rebored if not worn too thin. As these shells cover only about one-half the circumference of the axle, they are held in a special mandrel while being turned, which has collars between which they are clamped. The edges are then laid off for planing by applying a special gage to the box, as shown in Fig. 23. After the gage is set in the manner illustrated, it is placed on the end of the shell (as shown to the right) and lines are scribed representing the finished edges *e*, Fig. 22; the shell is then clamped in a V-block on a light rapid-running planer, Fig. 26, and the edges are finished. It is important that this planing be done with considerable accuracy, as the pressure required to force the brass into the box is determined largely by the fit of the edges. The ultimate pressure required to force

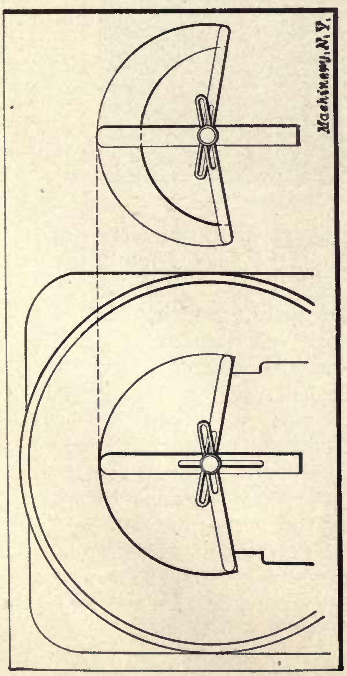


Fig. 23. Gage for Laying off Driving-box Brass

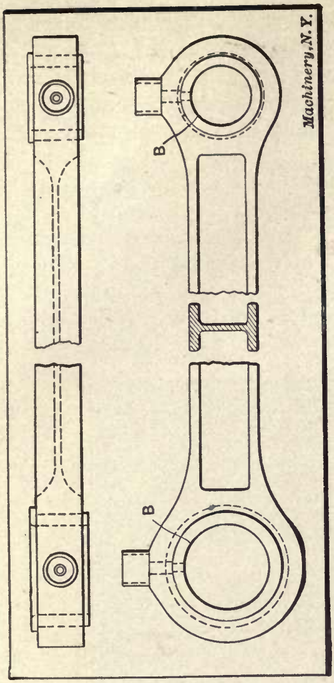


Fig. 24. Solid-end Side-rod

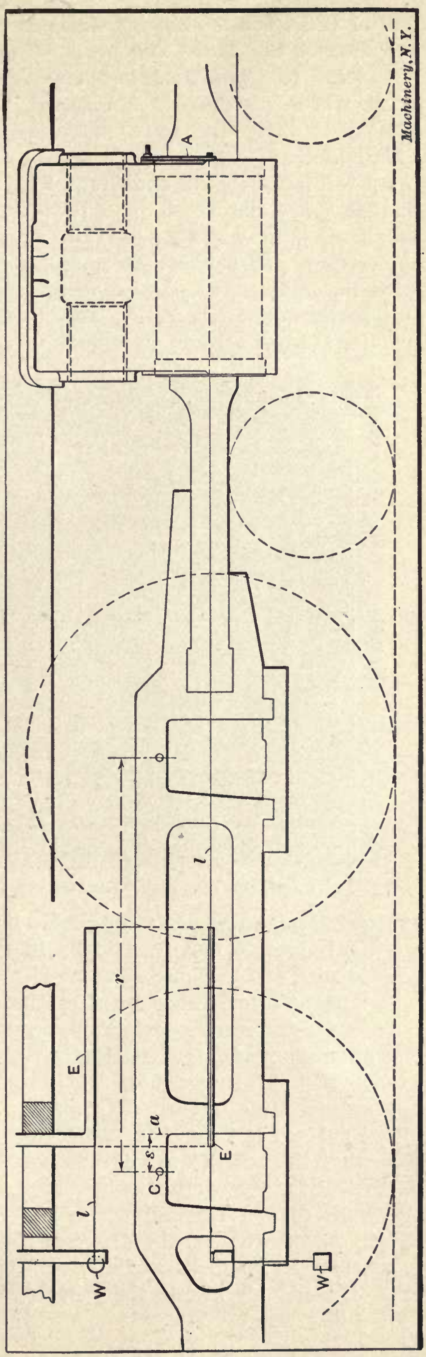


Fig. 25. Elevation illustrating First Operation connected with Truing Locomotive Frame Shoes

one of these shells "home" varies from 15 to 25 tons, depending upon the size of the box. The sides of the box are not planed until the shells are in place, as before stated, as they are usually sprung outward when the shells are inserted; therefore, planing is done after this distortion has taken place, as the sides of the box must be parallel.

By referring to the end view, Fig. 22, it will be seen that the box flanges *F* are slightly tapered toward the center. This is done to give the boxes and wheels a certain amount of angular movement with reference to the frame. As a locomotive at high speed strikes a curve with its inclined track, the wheels are, of course, also inclined, but the spring-supported boiler and frame, owing to their weight and inertia, tend to remain in a horizontal position; and are inclined less

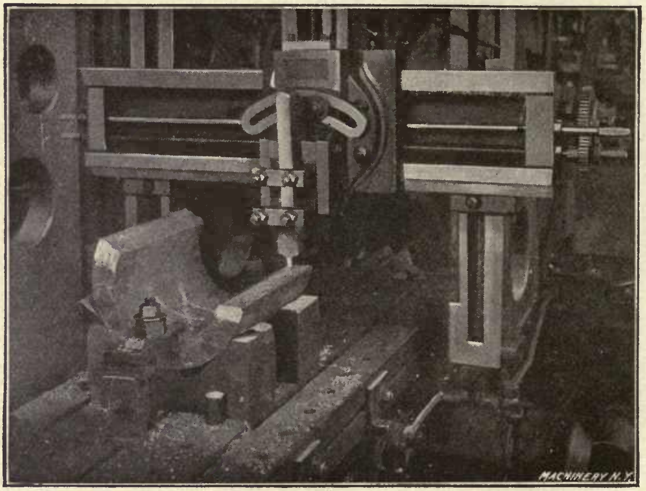


Fig. 26. Planing the Edges of a Driving-box Brass

rapidly than the wheels; therefore, if the boxes could not swivel and were only free to move vertically in the jaws, the flanges would probably break.

As the hubs or outer faces of the boxes against which the wheel hubs bear, are worn considerably, particularly when rounding curves, provision is made for eliminating this wear by babbitting the box faces. Fig. 27 shows how the boxes are babbitted, and also their appearance after the babbitt face has been cast on. When this babbitted surface is turned in the boring mill, which is done at the same time that the brass journals are bored, the amount of metal removed, or the thickness of the flange, is governed by the distance between the hubs of the driving wheels for which the box is intended. To obtain this thickness, the distance across the frames and shoe flanges is measured and also the distance between the wheel hubs; allowance is then made for giving the wheels about ⅛-inch lateral play.

Fitting Driving Boxes

After a driving box has been bored, it is given a more perfect bearing on the axle by scraping. A thin coat of black lead is applied to the journal, and the box, after being placed on it, is turned back and forth a few times which causes the black lead to mark the brass, thus showing the location of the bearing points. The box is then removed and the high spots are scraped, the object being to get a bearing that is evenly distributed. This bearing should, however, be somewhat "heavier" at the crown or top than at the sides. As the boxes on the large engines now in use weigh four or five hundred pounds a piece, the special hoist, or jib crane, shown in Fig. 28, was designed for lifting them to the journals when testing the bearing. This hoist (which is patented) is pneumatically operated, and is

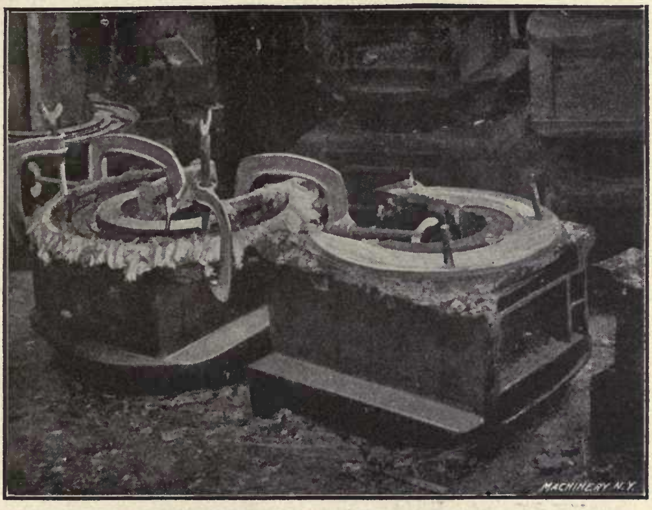


Fig. 27. Babbitting Sides of Boxes to take up Lateral Play

equipped with a swiveling, counterweighted trolley boom which, with the in-and-out movement of the trolley, enables a box to be placed in any position. By locating the hoist between two pairs of wheels, as shown, the four boxes can be fitted in a comparatively short time, owing to the rapidity with which they can be handled. A crane ring is attached to the top of the hoist column, so that it can easily be carried to any part of the shop.

Laying Out and Planing the Pedestal Shoes

One of the most important operations connected with the repair work on a locomotive is that of laying out and planing the pedestal shoes, as the boxes for the driving wheel axles are held in place by these shoes and their location determines the position of the wheels with relation to each other and to the frame and cylinders. When the driving wheels are not "square," that is, when their axes are not at right angles to the center-lines of the cylinders, the tire flanges

will be subjected to excessive wear and the rod bearings are liable to become heated, as the crankpins will not be in alignment. If the wheels are improperly located, it will also be difficult, or impossible, to enter the connecting-rods on their pins if the solid-end type is used; therefore, the bearing surfaces of the shoes must be properly aligned in order to have the wheel axles parallel with one another and at right angles to the cylinder center-lines.

The first step in this operation is to set fine lines *l*, Fig. 25, central with the counterbores of each cylinder. These lines are usually attached at the front to adjustable pieces *A*, held by the cylinder studs, and they should be long enough to extend back of the main jaws,

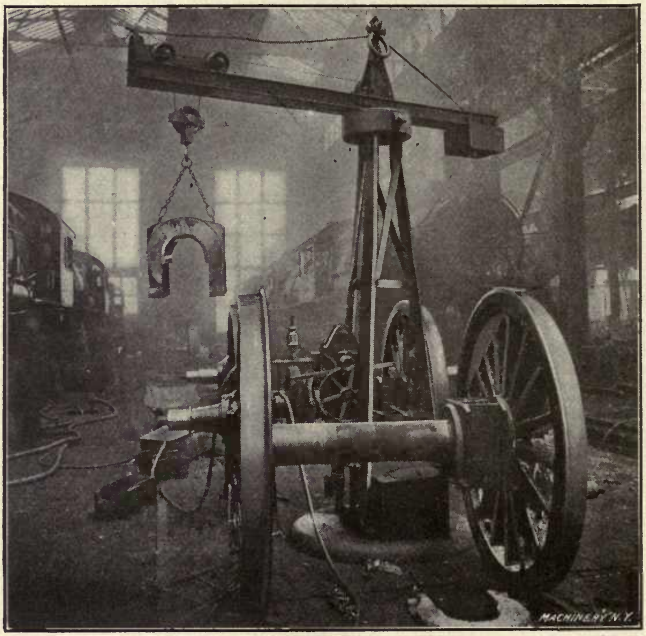


Fig. 28. Pneumatic Hoist used for Lifting Boxes when fitting them to the Journals

which are so named because they contain the main pair of driving wheels or the wheels that are connected to the crosshead by the main-rod. If weights *W* are attached to the rear ends of the lines, they will be kept taut even though the lengths change due to temperature variations. A sensitive gage for setting these lines can be made by inserting an ordinary pin in the end of a pine stick, having a length about 3/8 inch less than the cylinder radius and a diameter of 3/16 or 1/4 inch. After each line is set central, a long combination straightedge and square *E* is placed across the faces of the front main jaws and the jaws are tested with reference to the lines. If they are not square, a liner of the required thickness is placed between that jaw which is farthest forward and the straightedge, to bring the latter

at right angles to the lines. In case the lines are not parallel, the straightedge should be set as much out of square with one line as the other. Lines a representing the squared jaw faces are then scribed on the frames, and centers C are located, the distance s being obtained from a blueprint of standards giving this measurement for engines of various classes. The centers C will be in the same vertical plane as the wheel centers when the locomotive is assembled, and the object of this entire operation is to lay out the frame shoes for planing so that the thickness will be such as to bring the driving box centers (and consequently the axles centers) directly beneath centers C. After centers C are located for the main jaws, similar ones are made on the others by setting a long pair of trams to the respective rod

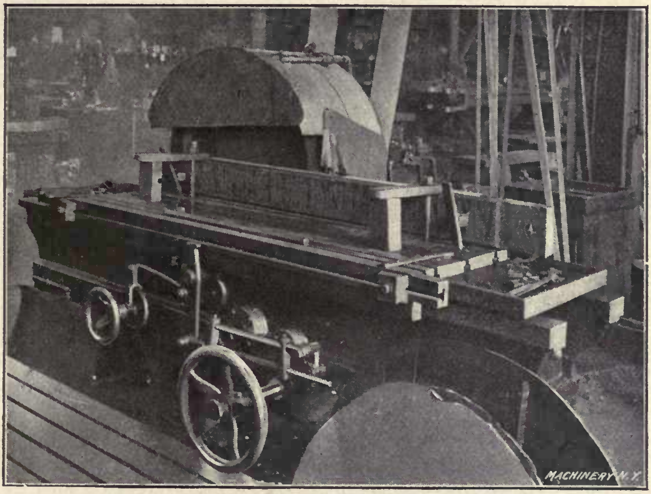


Fig. 29. Truing a Crosshead Guide by Grinding

lengths r. This measurement is also taken from the blueprint or table of standards, but the trams are set by a steel scale which is permanently placed in a central location in the shop. This scale has a number of parallel lines on it upon which there are punch marks for setting the trams, the various lines representing different classes of engines.

The shoes S and wedges W (Fig. 31) are put up next, and they are held against the jaws, temporarily, by spreaders t inserted between them. The wedges should be located (by adjusting bolts b) about ¼ inch above the pedestal braces B. After wooden centering strips are driven between the frame and pedestal braces and are set flush with the outer shoe flanges, centers m are located (in tin centering pieces) on a line passing through centers C and at right angles to the top of the frame. The height of these centers is not important, so long as their relation to the shoes is about as shown. The centers n of the driving-box journals are next found, and the distances x and y to lines on the flanges representing the front and back faces, are measured.

These dimensions represent, respectively, the distance that the finished shoe and wedge faces should be from centers *m*; if the shoes and wedges are old, it will be necessary to rivet liners to them so that the thickness will be increased sufficiently to permit planing. After the liners are riveted in place and the shoes are again in position, lines *o* are scribed on the outer flanges, the distance to them from centers *m* being one inch greater than the dimensions *x* and *y* The shoes are then ready for planing and are set for this operation by lines *o*. The faces are finished to within one inch of these lines, which remain as "witness" marks and show any inaccuracy in the work. The side lines on the boxes can easily be scribed by a transfer gage *G*, and a gage similar to that shown at *F* is convenient for testing the shoes and wedges when planing, the distance *f* being just

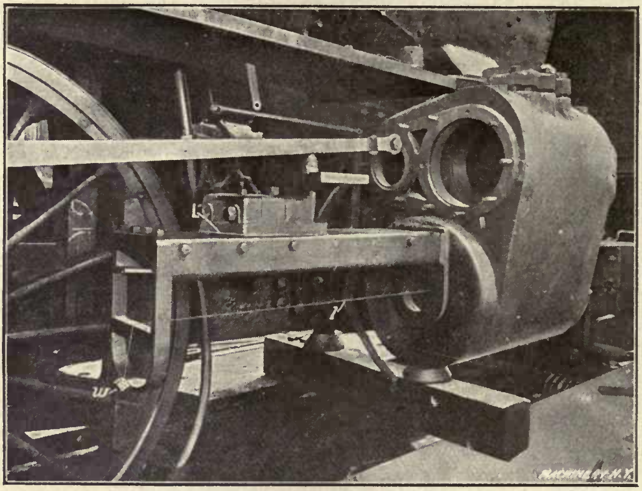


Fig. 30. Lining a Guide of the Box Type

one inch, so that the faces are planed until the conical point of the gage coincides with the lines *o* of the flanges. When a new set of shoes is being laid out, liners for increasing the thickness are not, of course, required.

Truing and Lining Guides

Steel crosshead guides are ground true in a face-grinding machine, as shown in Fig. 29, but the cast-iron single box-guide shown in Fig. 30 is trued by planing. The method of aligning the box type of guide with the cylinder is also indicated in Fig. 30. A fine line *l* is first stretched through the cylinder and back to the guide yoke. This line should be held taut by a weight *w*, and it is set central with the cylinder counterbore at the front and the stuffing box in the rear head. The guide is then set parallel with this line and a standard distance above it, changes in the alignment being made by inserting liners at *L* and also between the guide and block upon which it rests at the front. The guides that are located above and below the cross-

head—which is the arrangement with a crosshead of the "alligator" type—are aligned by first setting the lower guide to the correct distance below the cylinder center-line. This distance, if not standard, is determined by measuring from the lower crosshead bearing shoe to the center of the piston-rod hole. The top guide is then set parallel with the lower one and far enough above it to allow a free movement of the crosshead without unnecessary play.

By referring to Fig. 30 it will be seen that the box type of guide has a broad bearing for the top of the crosshead and a comparatively small one beneath. As this is a passenger locomotive and ordinarily runs in a forward direction, the thrust of the crosshead is upward, which is the reason why the top part is given a broad bearing. In

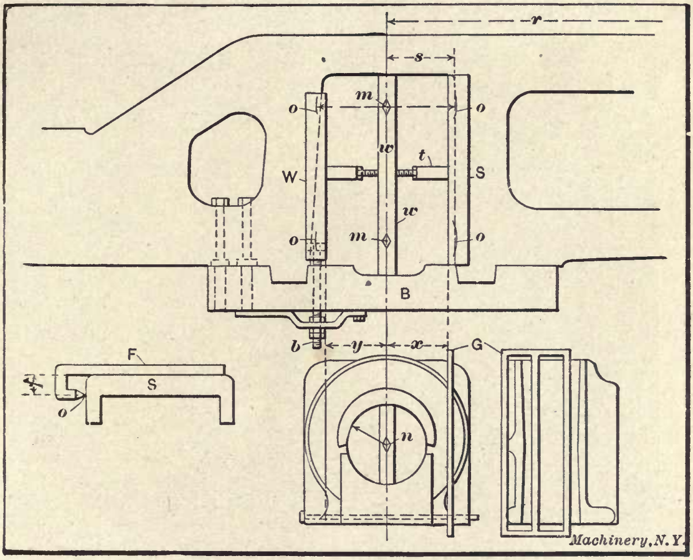


Fig. 31. Laying out a Shoe and Wedge with Reference to the Driving Box

Fig. 32 the method of babbitting the bearing surface of a crosshead to take up wear, is shown. The crosshead is placed in a jig having a taper plug that fits the piston-rod hole, and plate *A* is so located that the babbitt lining will be of the required thickness. After the metal has been poured, the side plates *B* are removed for withdrawing the crosshead, which is used without planing the babbitted surfaces. When planing a new crosshead, it is mounted on the piston-rod which is clamped in V-blocks as shown in Fig. 33. With this method, the bearing surfaces are planed in perfect alignment with the rod. After the top and sides have been finished, the under bearings are planed by turning the work until the top surface is at right angles with the platen.

Rod Work

As many of the side or parallel rods now in use are of the solid-end type with brass bushings instead of split brasses and a key for

taking up wear, the renewal of these bushings constitutes a large part of the rod work. The solid-end side-rod for an Atlantic type of locomotive is shown in Fig. 24. The worn bushings *B* are replaced by new ones which are bored in the special machine shown in Fig. 34, to fit the crankpins. As there is no way of adjusting the length of a rod of this type, the bushings have to be bored so that their center-to-center distance equals the distance between the wheel centers. As will be recalled, this latter measurement was taken from a standard scale when lining the frame shoes, and the rod lengths are also laid out with reference to this scale. By this method, the responsibility for any inaccuracy which would, for example, make it impossible to enter a rod on the crank-pins, could be fixed. When laying out the rods for length, circles are scribed on them and these are set con-

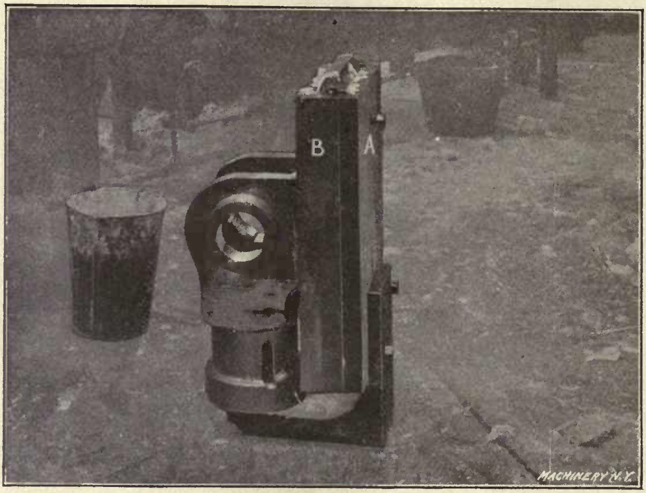


Fig. 32. Crosshead Babbitting Jig with Work in Place

centric with the boring machine spindles by a pointer that is attached to the spindle. A partial view of the rod department and also a pneumatic motor and stand for reaming rod bolt holes, is shown in Fig. 35. Flanged brasses of the split type, such as are used in the main-rod connections, are milled to fit their strips while held in the fixture shown in Fig. 36. The brasses, after being sweated together, are clamped in the fixture by a collar and nut as shown. After one side is finished by the end mill, the work is indexed 90 degrees, the swiveling base being positively located by the engagement of a taper pin *P*.

Throttle Valve Grinding

In Fig. 37 sectional views of two styles of locomotive throttle valves are shown. This valve controls the admission of steam to the cylinders, and it is located in the steam dome where the steam is comparatively dry. The throttle-box or chamber containing the valve, is mounted on an upright pipe that connects with a long steam pipe leading to the front of the engine where connection is made with the

cylinders. As the engraving shows, the valve is double, there being in reality two valves that are cast integral, and two corresponding seats S and S_1 in the throttle-box, so that steam is admitted in two places when the valve is open. With the valve shown to the left, which is the type principally used on the Pennsylvania, the steam that enters

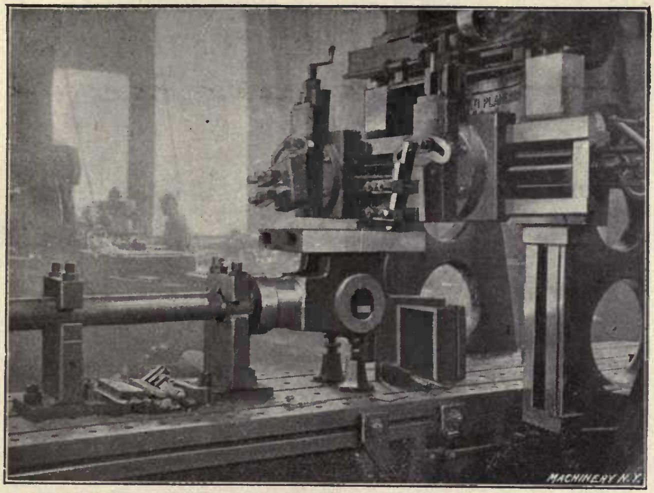


Fig. 33. Planing a New Crosshead

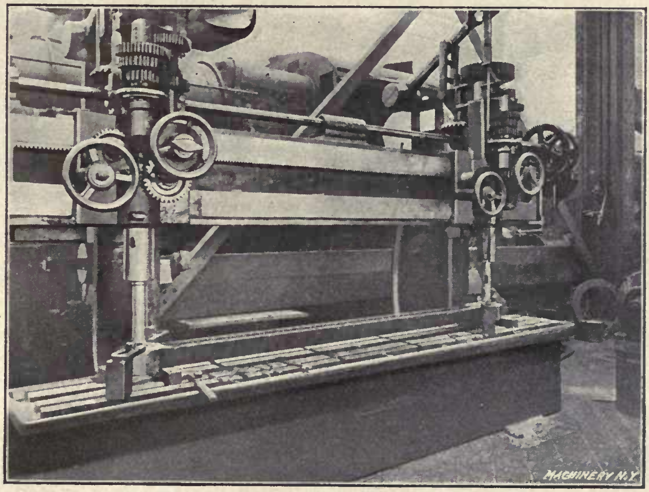


Fig. 34. Boring the Bushings of Solid-end Rods

through the lower seat passes down through the center of the valve. By referring to the illustrations, it will be seen that both of these valves are in balance so that a vertical movement can be effected with little effort. Were the throttle not balanced in this way, considerable power would, of course, be required to lift it against the steam pressure when starting a locomotive.

To prevent steam from leaking to the cylinders when the valve is closed, both the upper and lower valves must have a good bearing in their seats and both close tightly at the same time. The method of obtaining this bearing when a new valve is to be fitted or an old one has become leaky, is by grinding, emery and oil being used to abrade the valves and seats until they fit close enough to prevent the passage of steam. A throttle-box that has been removed from the dome and bolted to a bench for grinding, is shown in Fig. 38, which also illustrates a valve to the right. It is the practice to remove these boxes to allow the boilermakers to get inside the boiler and also to permit truing the seats in the lathe prior to grinding. A handle is attached to the valve for turning it, and before applying emery, the valve should be tried in its seat to ascertain where the heaviest bearing

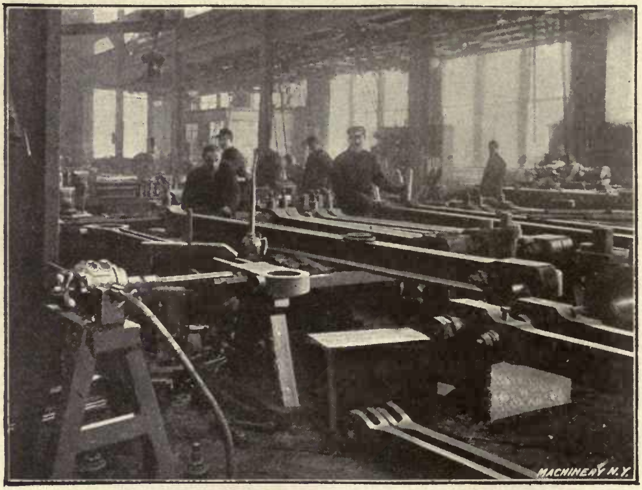


Fig. 35. View in Rod Department

occurs. This is important, as the upper and lower valves should be ground so that a good bearing is obtained on both at about the same time, if possible. If we assume that practically all the bearing is on the upper part of the valve, the grinding should be confined to that part until the lower valve gives evidence of a fair bearing; both seats would then be ground in together. By marking the valve with a number of chalk lines before testing, the bearing will be shown by the extent to which the chalk is removed. Emery is used as the abrasive, and most of the grinding should be done by a medium grade, No. 60 being about right. For finishing, a finer grade (about 80) is used. Oil is first applied to the bearing surfaces on the valve and then the emery is sprinkled evenly around these surfaces. The grinding is effected by imparting to the valve a reversing rotary movement, rather than a continuous movement in one direction, the valve being turned first one way and then the other for about one-fourth of a revolution. At frequent intervals, it should be lifted and occa-

sionally turned half way around; in this way the abrasive is kept distributed, and grooves, which would otherwise be cut in both the valve and seat, are avoided.

The time required for grinding a valve depends, of course, upon its condition at the beginning; if either the seat or valve are very much

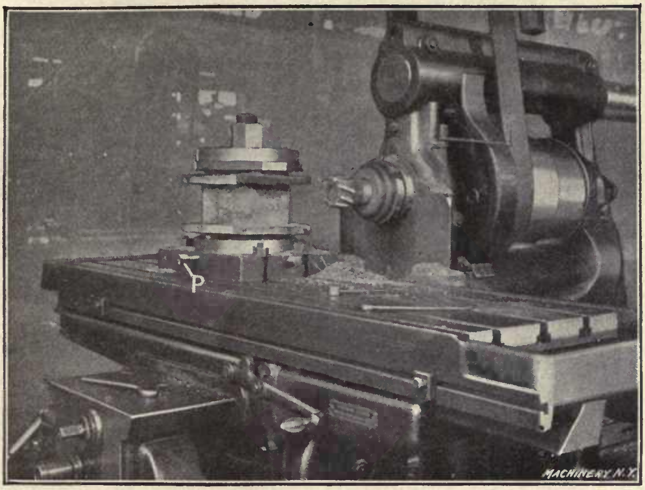


Fig. 36. Fixture for Milling Rod Brasses

worn they should be trued in the lathe before grinding. While the grinding operation is in progress, the bearing should be inspected every few minutes by wiping the seat and valve perfectly clean, and then turning the valve a few times, as when grinding, to mark the bearing. If the test shows that the upper valve has a heavier bearing

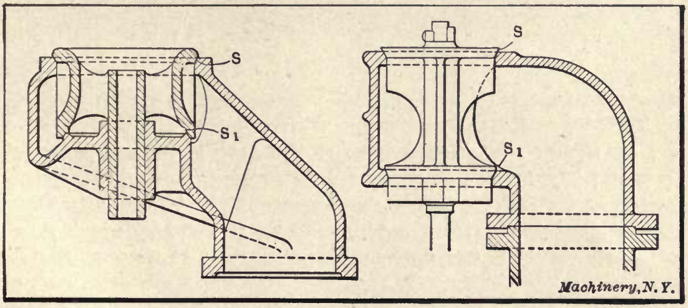


Fig. 37. Two Types of Locomotive Throttle Valves

than the lower one, or *vice versa*, this, of course, should be considered when the grinding is continued. If the difference is very pronounced, oil alone should be applied to that part of the valve having the lightest bearing. The grinding is continued until both valves show a bearing that indicates a good contact with their seats throughout the entire circumference. A valve that has been in service and needs

grinding sometimes has a very hard glazed surface on which emery has little abrading effect; in such cases pulverized glass is often used to grind away the hard outer surface.

The boiler check-valve is a very small and simple part of a locomotive, but nevertheless important, and often causes much trouble because of inattention, or what is even worse, careless attention. This valve, as all mechanics know, is located between the injector and the boiler, its function being to permit the passage of feed water to the boiler, without permitting any backward flow when the injector is not working. It is essential that the check-valve be tight and have the proper amount of lift. When it leaks, hot water is blown back, and the steam given off heats the injector and renders it incapable of starting, as the high temperature prevents the formation of a high

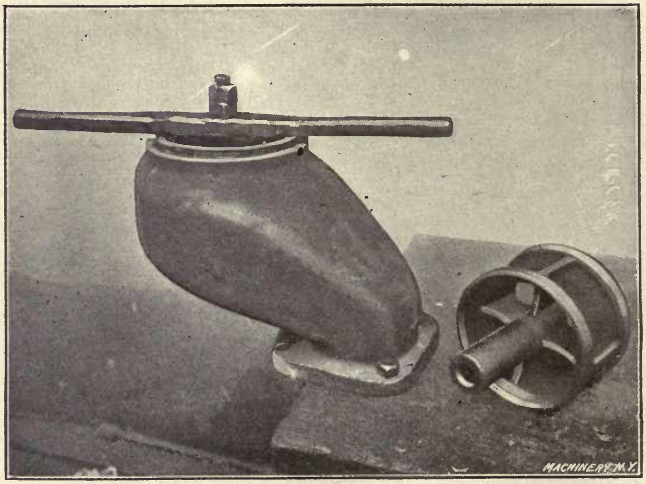


Fig. 38. Method of Grinding a Throttle Valve

enough vacuum in the injector to lift the water. Leaky check-valves are also made tight by grinding, the method of procedure being similar to that described in connection with the throttle valve, though, of course, on a much smaller scale. If the seat is pitted, reaming or a new valve body may be necessary. Frequently check-valves require cleaning more than anything else, particularly if the water used in the boiler contains calcareous matter, as the lime deposits or sediment interferes with the movement or seating of the valve.

Miscellaneous Repairs

In addition to the repairs previously referred to, there are numerous other parts which require attention before the work of overhauling is complete. The cab contains considerable apparatus, such as gages, valves, lubricators, injectors, etc., all of which are inspected and repaired if necessary. The valve mechanism is also put in order, but the extensive use of the Walschaerts valve gear (type illustrated in Fig. 47) on modern locomotives, lessens the amount of work neces-

sary on this part of the machinery. The casehardened bushings used in the different connections are renewed to eliminate lost motion, and any play between the link and link-block is taken up. Worn links are trued by grinding or lapping, and when a new link is required it is machined to the proper radius in the slotter which is equipped with an attachment similar to the one illustrated in Fig. 39, the particular one shown being a large size that is used for machining a radial surface on trailing wheel boxes. Very satisfactory work can be done with this attachment, which is simple in construction, but only applicable to a slotter having an adjustable head. What might be called the "radius rod" *R* is pivoted at *P* and the opposite end is securely bolted to the rotary table. When the slotter is being operated, the cross feed only is used, and as the longitudinal feed nut is unbolted from

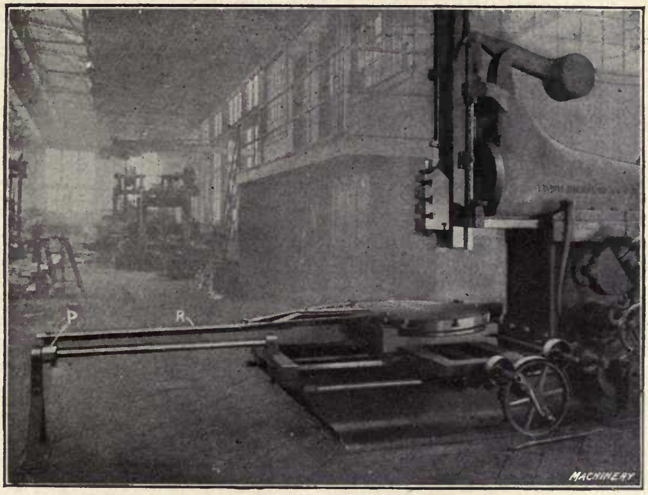


Fig. 39. Radial Slotter Attachment

the saddle, the rotary table and radius-rod turn about pivot *P*. As the table is moved either way from a central position, the lower or longitudinal slide is shifted toward the pivot, and it is to permit this movement that the feed nut is disengaged. The radius of the surface being planed is equal to the distance between the tool and pivot *P*, and the tool is adjusted for different radii by moving the head.

The Stephenson valve mechanism is much more cumbersome than the Walschaerts gear and also requires more attention. The large eccentrics and their straps wear rapidly, and the rocker arms which connect the eccentric rods and valve stems, also become worn and need repairing. The eccentrics are turned true in the lathe by mounting them on a mandrel having centers offset equal to the eccentric's throw. The straps are rebored to fit the eccentrics in a vertical mill, after being closed by reducing the thickness of liners between them, which are provided for this purpose.

Adjustment of the Spring Rigging

The arrangement of the spring rigging of an Atlantic type locomotive (E6 class) is shown in Fig. 40. When the engine is assembled, the weight is distributed between the front truck, the driving wheels and the trailer in the rear. The driving and trailing wheels are connected by a system of hangers *H* and horizontal equalizers *E*, and the entire rigging rests upon the wheel boxes, the frames and boiler being suspended on it with points of support at *a*, *b* and *c*. As the spring rigging is not rigidly connected, the equalizers being free to swivel about fulcrums *b* and *c*, there can be no variation from the proportioned distribution of weight.

A certain amount of initial tension is given to these springs before the boiler is lowered on the wheels, to prevent the frames from lowering too much after the spring saddles *s* are seated in the boxes. This tension is obtained by shortening the hangers *H*. The springs and equalizers are set in horizontal positions and the length of each hanger is made about 1½ or 2 inches short, so that to connect them it is necessary to pull down on the springs. Obviously, the weight of the boiler and its attached parts would have less bending effect on the springs when they are given this initial tension; in fact, if the hangers were not shortened, the frames would probably descend far enough to rest on the driving boxes and the boiler would not be spring supported. The amount that the hangers are shortened varies and can only be approximated. Occasionally it is necessary to alter the length of one or more hangers after the locomotive is assembled. This adjustment may be necessary to bring the rigging into the proper balance; for example, if the equalizers *E* swiveled from a horizontal position when the boiler was lowered in position, the length of one or more hangers would be changed sufficiently to straighten the equalizers.

Spring riggings are, of course, arranged differently on different classes of locomotives, as the arrangement depends on the design. Fig. 45 shows the spring-rigging for an engine of the 4-4-0 type, having a four-wheeled leading truck and two pairs of drivers. In this case the springs are placed beneath the driving boxes and instead of saddles (as at *s*, Fig. 40) on the boxes, the latter have attached to them beneath the journals, heavy hangers which hold up the springs and carry the weight of the boiler, excepting that which comes on the front truck.

Assembling the Locomotive

After the more important repairs have been made and the work of overhauling approaches completion, the front truck, driving wheels, and trailer, if the engine is so equipped, are assembled on one of the pit tracks and the boiler with the spring rigging in place, is lowered onto them by the cranes, the wheels being so placed that their attached boxes will enter the frame jaws. The shoes and wedges are then put between the frame jaws and boxes and the pedestal braces are bolted to the frames. After the wedges have been adjusted to take up all play between the box and jaws, the accuracy with which the frame

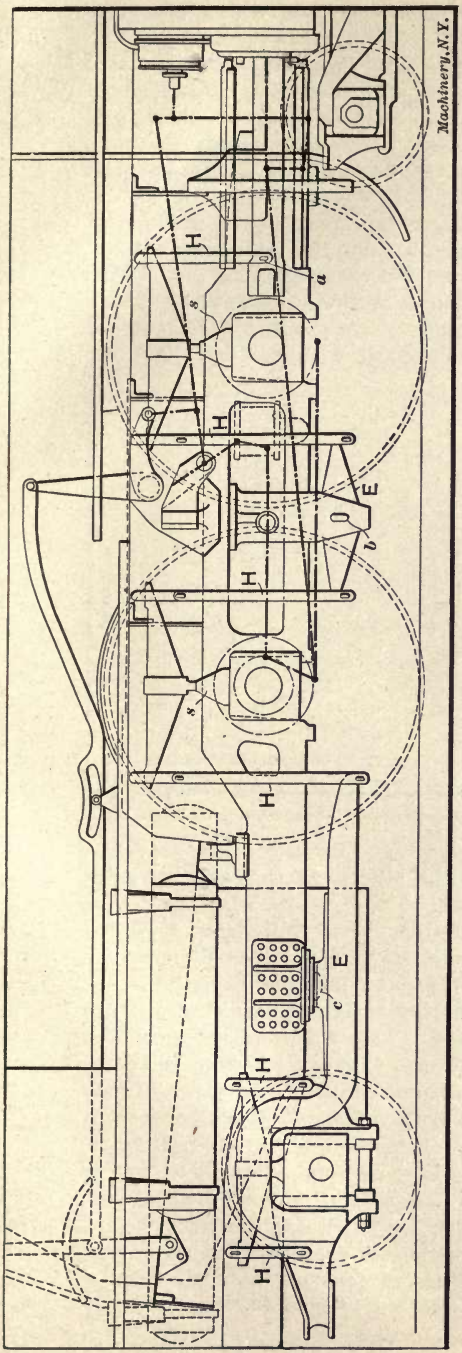


Fig. 40. Elevation showing Spring Rigging for Driving and Trailing Wheels, Atlantic Type Locomotive

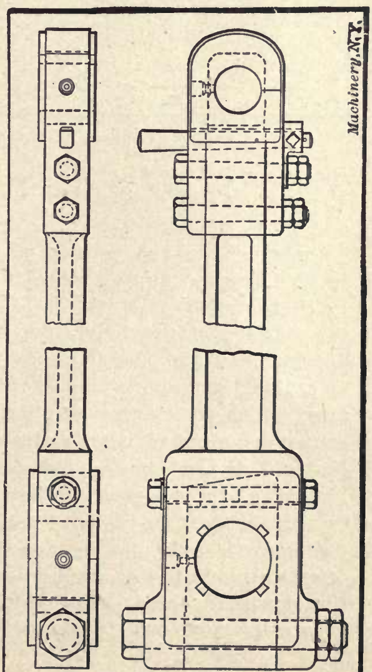


Fig. 41. Type of Main-rod which is lengthened by Keying

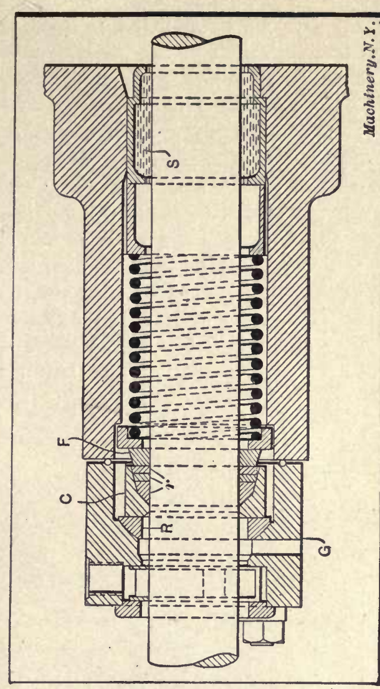
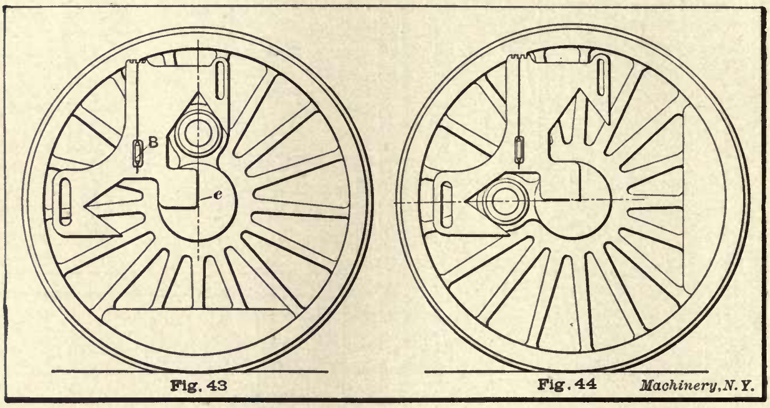


Fig. 42. Multi-angular Metallic Valve-stem Packing

shoes have been fitted is next tested by measuring with a tram the distance between the wheel centers on both sides of the engine. The large lathe centers are first hammered full of lead and a small center is located by a concentric circle previously turned in the axle end. If the trams show that the axles are not parallel, one or more shoes are removed and planed off as required. The distance between wheel centers must also conform to standard dimensions, if the solid-end type of side-rod is used.

The pistons are placed in the cylinders and keyed to the crossheads; the valve mechanism is coupled together and the main-rods are put up preparatory to setting the valves. Before assembling the pistons or front cylinder heads, any chips or other foreign material which may have fallen into the ports or other steam passages, are removed by compressed air. The boiler is connected with the "air line" for



Figs. 43 and 44. Application of Quartering Gage to Opposite Sides of a Wheel

operating hammers, etc., and the throttle is opened with the valves uncovering first one port and then the other. In this way all chips and dirt are blown out.

Inasmuch as the setting of valves has been fully treated in the technical press, and in other books on the subject, we shall not refer to that branch of work in this treatise. When the valves are set, the main-rods (previously put up for the valve-setting operation) are disconnected and the side-rods erected. With the solid-end type, this is ordinarily a short job, as the rods are simply pushed on the pins, after which the retaining collars are bolted in place. In case the rods cannot be inserted on the pins, and both rods and wheels have equal center distances, the trouble would probably be due to incorrect "quartering" of the pins. This, however, is a rare defect and one that is equally difficult to remedy, it being necessary to force the wheel center from its axle and replace the hub key with one having sufficient offset to move the crankpin to a position 90 degrees from the one in the opposite wheel. The pins are tested for this inaccuracy by a quartering gage which is applied as shown in Fig. 46. This gage is

intended more particularly for testing new wheels after they have been pressed on the axles. It is placed on one of the pins, as shown in Fig. 43, with edge *e* in line with the axle center; the wheels are then adjusted until the center of the pin is in a vertical position relative to the center of the axle, which is shown by the coincidence of the point of plumb-bob *B* with a line on the gage. The pin on the opposite side is then tested as shown in Fig. 44, and any deviation of the plumb-bob from the vertical, as shown by its point, indicates that the angular distance between the pins is either greater or less than 90 degrees.

The erection of side-rods having straps, split brasses and keys for taking up wear, requires a great deal more time than the solid-end rods, but as the strap type is little used on modern locomotives, their erection will not be considered.

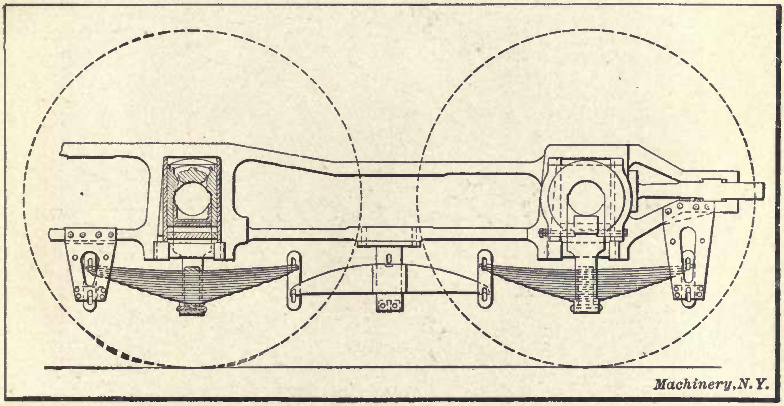


Fig. 45. Spring Rigging for 4-4-0 Type Locomotive

When putting up the main-rods, the length of the rod is the important thing to consider. As the piston when at the extreme ends of its stroke travels close to the cylinder heads (within 1/8 or 3/16 inch), the length of the rod is adjusted to equalize this clearance space. As the distance between the main driving wheels and the cylinders is practically standard, and as the piston-rod and crosshead are also made to standard dimensions, the length *L* (Fig. 47) of the main-rod requires little alteration, but a certain amount of adjustment is necessary to compensate for slight variations that often occur. This adjustment is made by changing the position of the bearing brasses by inserting liners of the required thickness either in front or back of them as may be required. Before putting up the main-rod, the positions of the crosshead when the piston strikes the front and back cylinder heads, are marked on the guide; these marks are known as "striking points", and are indicated at S and S_1. The rod length is determined by placing the crankpin on one of the "dead centers" as shown, and noting the position of the crosshead with reference to the forward or back striking point, as the case may be. For example, if

the crosshead shows that practically all the clearance (the total amount of which should first be measured) is at the rear, the rod should be shortened. In dividing the clearance, it is well to consider whether or not the rod will be lengthened or shortened as the brass wears and that wear is taken up by the taper key. There will be little change with the design of rod shown in Fig. 47, as tightening the front and back end keys K and K_1 shifts the brasses in the same direction. On many locomotives the rod lengthens as the brasses wear and the key is driven down, in which case the clearance should be greatest at the front of the cylinder to compensate for this gradual increase in length. A main-rod of the type which lengthens is shown in Fig. 41, both keys in this case tending to force the brasses further apart.

After the rod length is determined, the final adjustment of the keys

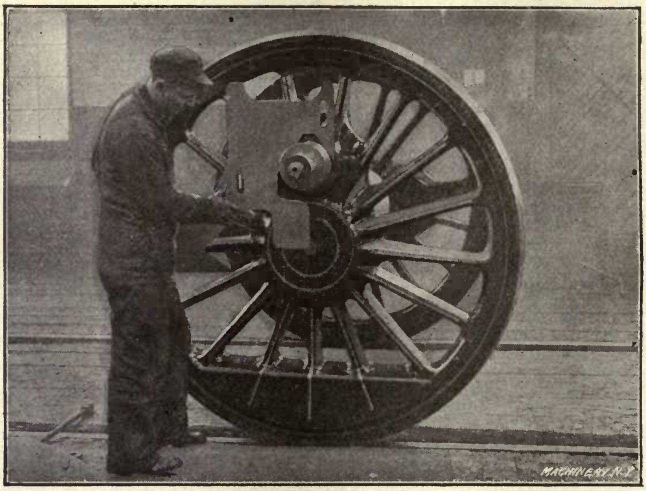


Fig. 46. Testing Location of Crankpins with Quartering Gage

K and K_1 should be carefully made to eliminate any unnecessary play in the bearings. If the brasses are keyed too tight, the excessive friction will cause them to "run hot," and if a key is not tightened enough, there will be a "pound" in the connection, owing to the excessive play. The proper way to key a strap connection is to drive the key much tighter than would be required under running conditions to draw the parts up solid; the key is then slackened and again tightened sufficiently to take up all play between the brass and pin, but the rod should move laterally on the pin with little effort, aside from that required because of its weight.

Metallic packing is now universally used on locomotives to prevent any leakage of steam past the piston and valve stem, as it is much more durable than any fibrous packing, if the composition of the packing rings is correct and it is properly applied. Fig. 42 shows a sectional view of the packing and gland for a valve stem. This is known as "multi-angular" packing and consists of a vibrating cup C contain-

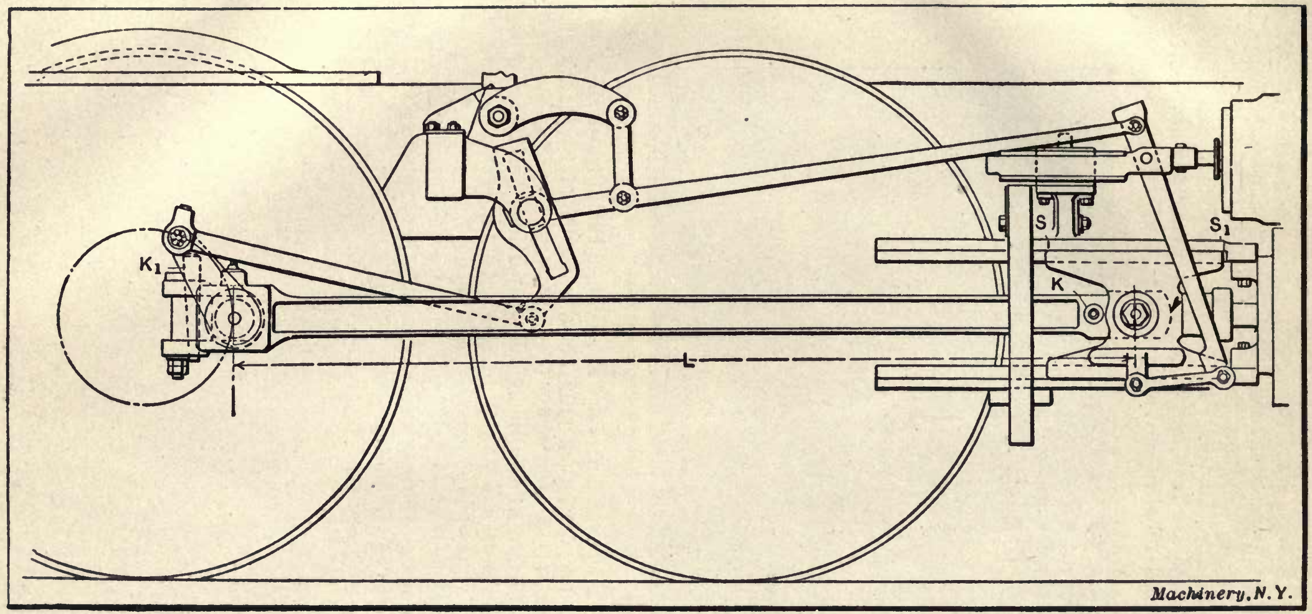


Fig. 47. Elevation showing Walschaerts Valve Gear, with Main Rod on Dead Center

ing three soft metallic rings *r* which are bored to fit the valve stem. These rings are pressed in the cup by a spiral spring, as shown, which acts against a follower ring *F*. As the rings are worn by the action of the valve stem, they are automatically fed into the conical vibrating cup which closes them around the rod, thus compensating for the wear as fast as it takes place. The vibrating cup rests against ring *R*, which has a ball joint bearing in the gland *G*, so that any rocking movement of the valve stem is accompanied by a corresponding movement on the part

of the vibrating cup and packing rings. These rings are located quite a distance from the steam chest to prevent that part of the stem which is worn by supporting ring *S* from reaching them, which would cause a "blow" or "leak." The piston-rod packing is arranged practically the same as that for the valve stem. As a great many packing rings are required where over twenty engines are constantly undergoing repairs, the various sizes are cast in the molds

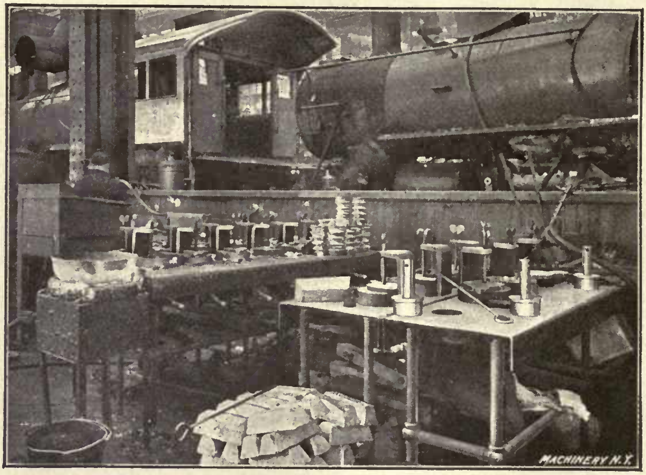


Fig. 48. Molds in which Metallic Packing Rings are Cast

shown in Fig. 48. These molds are shaped like the finished rings and when the rings are cast, they only need to be bored to fit the particular rod or valve stem for which they are intended. The rings are held while being bored in a cup-mandrel, shaped like the vibrating cup.

When the work of assembling is completed and any lagging or jackets which may have been removed, are replaced, the final operation, which adds a finished appearance and makes a greater showing than all the other work combined, is performed by the painter; the locomotive is then ready for another turn on the road.

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